HEAT CONSUMPTION ANALYSIS AND ENERGY-SAVING RENOVATION OF BUILDING HEATING IN HIGH SUNSHINE HEATING AREA

by

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In order to explore the effect and influence of energy-saving renovation on buildings in high sunshine heating area, the method of visit survey is used. The main scope of reconstruction includes: building windows, walls, door joints, pipe network, insulation measures, etc. The heat consumption of buildings, the comprehensive effect of improvement, and the satisfaction of residents are studied. The results show that after the energy-saving renovation of buildings and equipment in the heating area, compared with before the renovation, the residents' awareness of saving heating has been greatly improved and the waste has been significantly reduced. With the decrease of heating economic expenditure, people are more satisfied with energy-saving renovation. Both heating companies and individual users have been relatively large expenditure reduction. To sum up, it is very important to improve the energy efficiency of buildings in high sunshine heating area. After the energy-saving renovation of the building, not only the awareness of saving is improved, but also the consumption of resources are reduced, so that more people can enjoy the warmth. A win-win situation in the cost of users and heating companies is achieved. This study has a positive effect on the follow-up research of building energy-saving renovation in heating area.

Key words: *photovoltaic, cell, storage, fuel, load*

Introduction

With the development and progress of society, the tense situation of energy is very severe, and the social environmental problems are also extremely acute [1]. Therefore, it is very important to save the waste and consumption of energy so as to reduce the pollution the social environment [2]. At present, in the heating process of urban residents, the consumption of resources is very large, and it will also bring great air pollution. Therefore, how to save the waste of heating resources is very urgent [3]. In this study, the main way to improve the energy efficiency of the building is to reduce the consumption of heating and other factors caused by waste, and energy flow is generally achieved through conversion [4]. At present, the main raw material for heating in China is coal [5]. The burning of coal will bring serious haze and pollution. In particular, China's population is large, and the coal consumption is very large. Therefore, energy conservation and pollution reduction are very important for improving heating efficiency [6]. The use of coal plays a very extensive role in daily life and after conversion and processing, it can become the power to make a lot of things [7]. If the efficiency of improvement is relatively low [8, 9], and there is

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no efficient energy utilization and no substantial improvement in saving technology, there is no way to steadily carry out energy saving and environmental improvement [10]. Resource saving is extremely important in any field, so it is indispensable for any energy consumption industry to find efficient energy-saving technology to improve and innovate buildings, improve energy utilization, and reduce pollution and risk [11]. Therefore, the focus of this study is to study the heat consumption of buildings, the comprehensive effect of improvement and residents' satisfaction.

In this study, the interview survey method is used to analyze the energy-saving renovation of buildings in high sunshine heating area, and to study the heat consumption of buildings, the comprehensive effect of improvement and residents' satisfaction. The innovation of this study lies in more detailed research and comparative analysis of the situation before and after the energy-saving renovation. At present, most of the research direction lies in the energy-saving renovation itself, so this study has a very important value for the future research on building heating energy-saving renovation.

Methodology

Heat consumption analysis of building heating

The simplified heating energy consumption model of buildings with central heating system can clearly see the main tasks and objectives of heating energy conservation in northern cities and towns of China [12], and the three basic transformation contents specified in the guidelines are based on the analysis of the sources of heating energy consumption. The heating energy consumption, **W**, of buildings with central heating system:

$$\mathbf{W} = P + \left(Q + C_1 A + C_2 A\right) C_3 \tag{1}$$

where P [W] is the water spring energy consumption of the pipe network, accounting for 3~5% of the heating building energy consumption. When the heating capacity is fixed, it is related to the temperature difference between the supply and return water. The larger the temperature difference is, the smaller P is. The Q is the actual heat demand of the building.

Transformation of thermal insulation performance of peripheral protection structure: through deformation of the actual heat demand equation of the building in the model, the heat demand per unit volume of the building can be deduced:

$$q = \frac{Q}{V} = \frac{KF\Delta t}{V} = K\varepsilon\Delta t \tag{2}$$

where q [Wm^{-3}] is the building heat demand per unit volume, V [m^3] – the volume of the building, and ε [m^{-1}] – the figure coefficient.

$$\begin{aligned} Q_E &= \left(t_i - t_o\right)\left(\sum KF\right) \\ Q_{\mathrm{L}} &= \left(t_i - t_o\right)0.000278 n_k V_n c_p \rho \\ M_1 &= \sum\left(Q_E^{'} + Q_L^{'} - Q_E - Q_L\right) t_h A \sigma_1 \end{aligned} \tag{3}$$

where Q_E is the heat transfer of the building envelope, t_i and t_o – indoor and outdoor temperature, respectively. The Q_1 is the heat loss due to infiltration of cold air.

Heat source and pipe network heat balance transformation: for large-scale urban heat network, the maximum heat loss caused by uneven end can be up to 30%.

The imbalance rate of the pipe network:

$$\delta = \frac{\Delta t_p - \Delta t_r}{\Delta t_p} 100\% \tag{4}$$

The calculation equation of the heat transmission and distribution of the pipe network and the energy saving effect after the transformation of the heating pipe network:

$$L = \Delta tcG$$
$$M_2 = \left(L^{/} - L\right)\sigma_2 \tag{5}$$

Comprehensive energy saving effect of the transformation scheme:

$$M_3 = \frac{\left(E^{/} - E\right)\sigma_3}{\xi\eta} \tag{6}$$

$$M = \max\left(M_1 + M_2 + M_3,\ M_1 + M_3,\ M_2 + M_3,\ M_3\right) \tag{7}$$

Cost-effectiveness ratio:

$$\Phi = \frac{\sum S}{M\gamma} \tag{8a}$$

Static pay-back period:

$$\Psi = \frac{\Phi}{R} \tag{8b}$$

where M is the energy-saving effect of the transformation scheme, Φ – the cost-effectiveness ratio, S – the investment of transformation scheme, γ – the conversion factor, G – the pay-back period, and R – the heat price.

Research on current energy consumption characteristics of heating buildings

The thermal insulation performance of the building envelope is poor. The thermal insulation of the building envelope and the air tightness of the doors and windows are the main internal factors that affect the building energy consumption [12]. The heat loss of the enclosure accounts for 70~80% of the total heat loss of the building. The heat loss of air penetration through the gap between doors and windows accounts for about 20~30% [13]. Therefore, these two aspects are also the key points of energy-saving renovation. The main materials, equipment and technology used in residential buildings in the province are not significantly different from those in developed areas or even abroad [14], and the main gap lies in the design standards. Therefore, the transformation of envelope structure is one of the key points of building energy-saving transformation. The incentive research of building energy-saving renovation is shown in fig. 1.

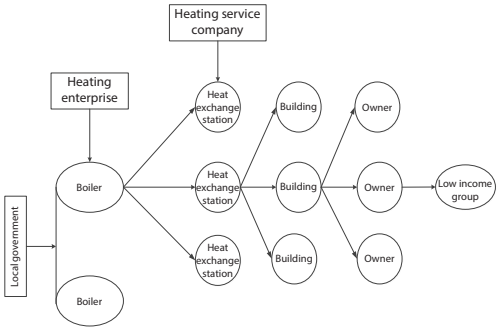

Figure 1. The incentive research of building energy-saving renovation

The heating efficiency of the existing residential building heating system is low. About 50-60% of building energy consumption in China is heating and air conditioning. The heat source of central heating in Lanzhou is mainly coal-fired boiler [15]. At present, the single thermal power of boilers in China is generally small, the thermal efficiency is low and the pollution is serious. The operating efficiency of the boiler is only 55~70% [16]. The heat preservation and insulation performance of the heating transmission and distribution network is poor, and the

transmission efficiency of the outdoor network is 85~90%, that is, the effective heat input from the boiler into the network will loss 10~15% in the process of transmission along the way, and the remaining heat is supplied to the building for heating [17]. The comprehensive efficiency of the whole heating system is only 47~63%, which is far below the level of 80% in advanced countries. Moreover, the power and water consumption of the whole system is extremely high [18].

Indoor heating system is not conducive to household regulation. The idea of externality internalization of energy-saving transformation of residential buildings is shown in fig. 2. The existing indoor heating system of residential buildings does not achieve room temperature control. Users cannot adjust the heating capacity according to their own needs. The heat consumption is completely determined by the temperature of the water supply and return and the flow in the pipe, and the heating time and temperature cannot be controlled by the user. There is no direct relationship between the user's heat consumption and the heat fee paid. Therefore, most households do not form a good sense of energy conservation. Only when the indoor system is reformed to make the heat consumption of households linked with economic benefits, its energy saving effect will be more significant.

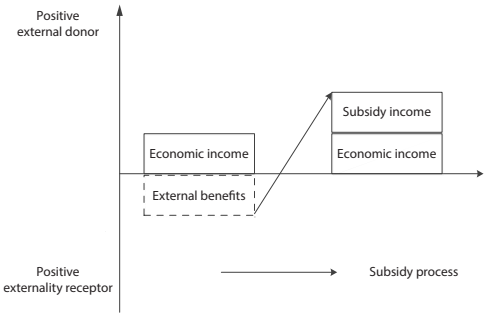

Figure 2. Thoughts on internalization of externality in energy-saving renovation of residential buildings

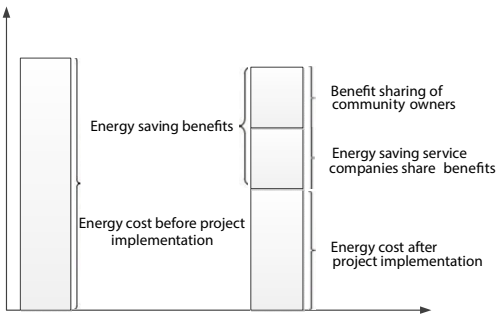

Figure 3. Energy saving operation diagram of building energy saving renovation management mode

Specific measures for building energy-saving renovation

It can be seen from the previous analysis that, combined with the heating metering transformation, the energy-saving renovation of the existing heating buildings should be carried out from three aspects of the heat source pipe network, the enclosure structure and the indoor pipe network, meeting the energy-saving requirements of 65% specified in *The Heating Residential Energy Saving Design Standard*. The energy-saving operation of building energy-saving renovation management mode is shown in fig. 3.

Transformation of heat source pipe network: first, the automation and energy-saving renovation of heating point equipment and circulation system is carried out with frequency conversion device, and the total annual power consumption is reduced by 20%; the second is to complete the transformation of heating system according to the requirements of variable flow automatic control operation. In the primary and secondary network of the circulation system and the main return pipe of each building unit, self operated temperature control valve is installed; the third is to carry out the transformation of energy conservation and consumption reduction in heating stations. By using layered and branch coal feeding technology, the thermal efficiency of the boiler is obviously improved, and the carbon content of the slag is further reduced; the fourth, if the thermal insulation of the original heating pipe-line fails to meet the requirements, the thermal insulation layer (polyurethane spraying thermal insulation material) shall be added again, the glass cloth shall be wrapped, and the outer surface shall be brushed with glass glue.

Reconstruction of the enclosure structure: the heat transfer coefficient of the enclosure structure of the existing heating building is large, the air tightness of the building is poor, and the cold air infiltration is serious, which increases the heat load of the terminal heating building. Therefore, the external wall insulation and roof insulation should be carried out for all buildings. Different transformation schemes should be adopted for different doors and windows to improve the insulation performance and tightness of the building and reduce the cold air penetration of the building. The external analysis of energy-saving renovation of residential buildings in the heating area is shown in fig. 4.

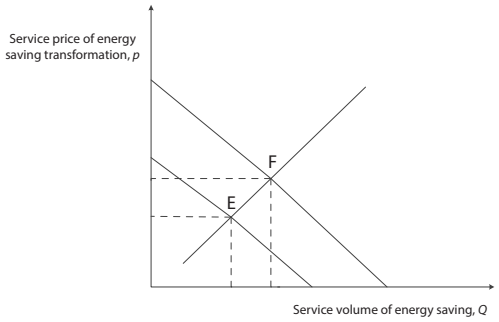

Figure 4. The external analysis of energy-saving renovation of residential buildings in the heating area

Energy saving renovation of pipe network: the improvement of building energy saving mainly includes many factors, such as the ratio of windows to walls, body index, and thermal insulation measures. Therefore, it is very important to carry out household measurement and building measurement, which can effectively reduce the heating cost of residents, save energy and resource consumption, and obtain greater economic benefits. The improvement of economic benefits will promote the improvement and innovation of the whole building to expand, promote the rapid progress of the project, and accelerate the establishment of energy-saving buildings. If the measures are not appropriate, it will also bring great negative effects. On the one hand, it will increase the heating cost of residents. On the other hand, it will also cause the building to overheat.

The continuous improvement of building windows can effectively save energy and waste, so the behavior of opening windows should be criticized by the society and public opinion. Through mutual supervision, improving the user's personal quality and saving consciousness is the fundamental point of the final problem. The market configuration diagram of energy-saving renovation of residential buildings in heating area is shown in fig. 5. Through the market-oriented behavior and measures, the improvement and development of heating technology of residential buildings are promoted. On the one hand, it continues to improve through the design of the building. On the other hand, strengthening the thermal insulation measures of external pipelines can greatly reduce the energy consumption of other factors. The supply efficiency of heating can be improved significantly by improving the heat source efficiency, terminal regulation and pipe network system.

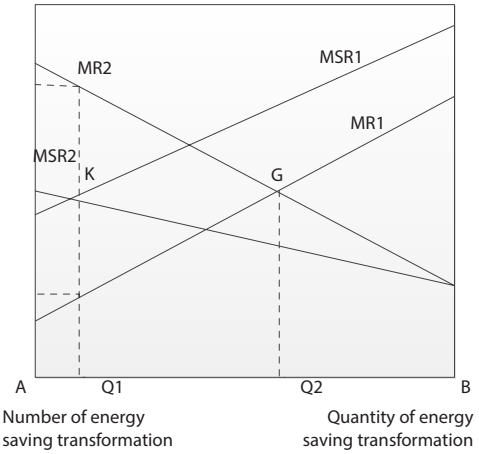

Figure 5. Market configuration of energy-saving renovation of residential buildings in heating area

Study on the effect of energy-saving renovation

After heat metering, the residents will use different ways to save heating time according to their actual income. During the *Spring Festival*, the residents who go out or live without people for a long time will turn down or close the heating valve, so as to minimize the cost of heat. The interaction relationship between the main bodies related to the energy-saving renovation of residential buildings in the heating area can be seen in fig. 6. It can be concluded that long-term residents or other types of households invest in the purchase and installation of heat meters. In winter heating, spontaneous energy-saving, out to close the valve or close the small valve can save heating costs. The average input-output ratio is 85.4%. An average of 1071 Yuan* is saved every year. The initial 1500 Yuan can be recovered after 1.2 heating period. According to the guaranteed service life of JRN intelligent household heat metering device and management system of 12 years, the average household saving is 11360 Yuan.

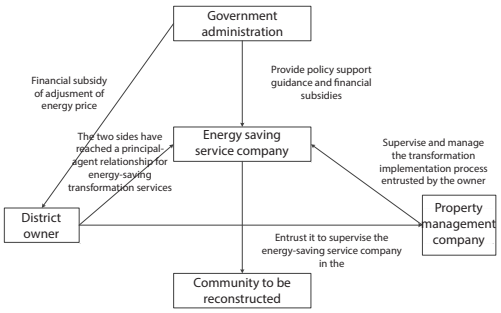

Figure 6. Interactive relationship diagram of main bodies related to energy-saving renovation of residential buildings in heating area

At present, most of the district heating is mainly provided by municipal heating companies. Since the installation of the system, the heating company manages and communicates through the terminal system, and carries out the pre charging and remote efficient management. Therefore, residents need to pay in the charging hall. The work intensity and efficiency of personnel have been reduced. The management ability of the single supply has also been improved, so as to achieve the purpose of overall improvement. Since the installation of metering devices in each household, the residents' awareness of conservation and protection has been significantly improved. When the user is not at home or out for a long time, the household will consciously close or lower the valve, saving energy and reducing economic expenditure. Most of the residents have also retrofitted and renovated the windows of the building. In this way, the purpose of energy conservation and cost reduction can be achieved in essence. The operation of the decision-making mechanism for energy-saving renovation of residential buildings in the heating area is shown in fig. 7.

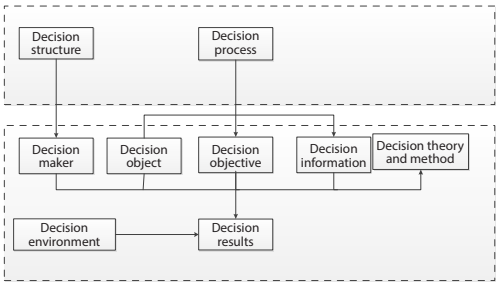

Figure 7. Operation diagram of decision-making mechanism for energy-saving renovation of residential buildings in heating area

The technology of measurement and renovation has been implemented. Frequency conversion equipment is used to control, update and improve the automation of circulation system and heating machinery. The heating system is improved and optimized according to the flow control technology to ensure that the flow can be controlled and optimized by itself. The third aspect is to improve and innovate the boiler with layered technology, so as to reduce the waste of energy, save and protect resources, and significantly improve the utilization efficiency of the boiler. Through these specific technical improvement measures, users' awareness of energy conservation and protection is significantly improved. Therefore, building based energy-sav-

* 1 Yuan = 0.14 $

ing improvement measures are very important livelihood projects.

Results and discussion

The research on the influence of building reconstruction on residents' heating awareness is shown in fig. 8. It can be seen that after the energy-saving renovation of heating buildings and equipment for residents, compared with before the renovation, the awareness of saving heating for residents after the renovation has been greatly improved, the proportion of closing valves and closing small valves has been significantly increased, and the proportion of not closing valves has been greatly reduced. Therefore, the necessity of energy-saving renovation can be seen.

The loss analysis and research of residential buildings before and after energy-saving renovation are shown in fig. 9. Compared with the heating loss before the energy-saving renovation, the heating loss of residents after the renovation has been greatly reduced. Doors, windows, walls, pipe networks and other equipment, have a very significant loss reduction. It can be seen that energy-saving renovation plays a very important role in heating and saving social resources. Such actions can save social resources to the greatest extent and reduce economic expenditures.

The research and analysis of the cost of heating before and after the transformation are shown in fig. 10. From the data and trend chart in the figure, it can be seen that after the energy-saving renovation, the heating cost of the five households randomly surveyed in this study has dropped by about 20%, which significantly reduces the economic expenditure and reduces the waste of resources. It can be seen that the energy-saving renovation based on the building is very necessary. It will not only benefit the people but also bring great welfare to the whole society. It should be vigorously supported and promoted to improve the utilization rate of heating.

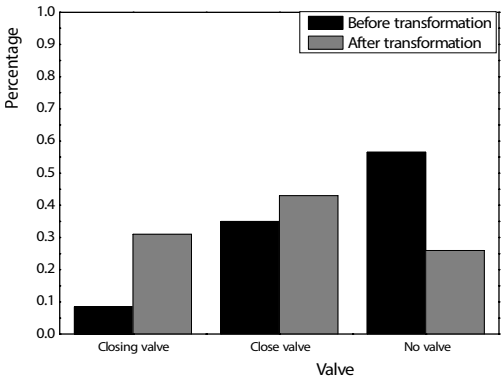

Figure 8. Research on the influence of building reconstruction on residents' heating consciousness

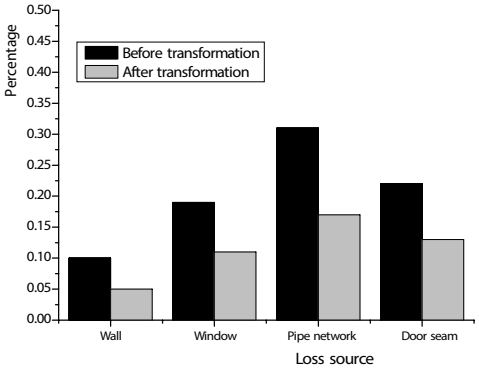

Figure 9. Analysis and research on the loss of residential buildings before and after energy-saving renovation

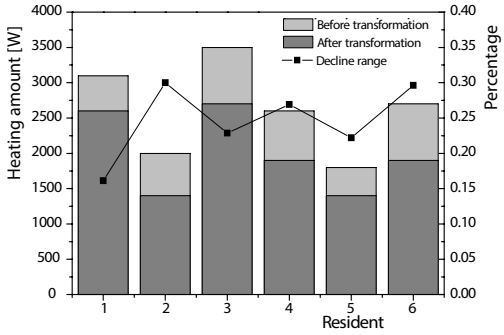

Figure 10. Research and analysis on the cost of residential heating before and after reconstruction

Conclusion

In this study, the interview survey method is used to analyze the energy-saving renovation of buildings in high sunshine heating area. The comprehensive effect and people's

satisfaction after the transformation are studied. The results show that the energy-saving renovation of buildings in heating area can achieve the purpose of energy conservation and emission reduction, form a good social effect, and reduce the social and economic expenditure and burden. There are also some deficiencies in the research process of this study, mainly reflected in the conclusions of the research on building energy-saving renovation in heating areas are more out of investigation and data, for the actual situation and data cannot be obtained due to the limitations of objective factors, so there will be many interference factors and the results are not convincing. However, this study provides a valuable reference for the follow-up research on building energy-saving renovation from a qualitative point of view.

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